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FINAL REPORT
DIGITAL DISPLAY INDICATOR
IP-1351/AVQ-30(V)

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Prepared By
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Report NADC-78080-60 Volume 1

Reliability and Maintainability Improvement Program
for the AV-8A/TAV-8A Harrier Head-Up Display Set,
Modifications to Digital Display Indicator, IP-1351/AVQ-30(V)

Smiths Industries Inc.
Aviation Division
Clearwater, Florida

1 May 1980
Final Report

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17. SUPPLEMENTARY NOTES This report (Volume 1) covers the DDI portion of the work done under the contract. Other reports, (Volume 2 and Volume 3), cover the DSC and SDC portions respectively of other tasks.			
18. KEY WORDS (Continue on reverse side if necessary and identify by block number) (U) Head-up Display (U) V/STOL Aircraft (U) Displays			
19. ABSTRACT (Continue on reverse side if necessary and identify by block number) Modifications were made to the head-up display unit on the AV-8A aircraft, to improve reliability. The modifications consisted of substituting a quick-release dual combiner for the servo-driven single combiner, providing circuit protection against high voltage insulation breakdown, providing BIT-fail format indication in Test Mode 1, and U.S. sourcing of all components.			

ABSTRACT

This final report summarizes the modifications performed on the Digital Display Indicator (DDI), IP-1351/AVQ-30(V), a weapons replaceable assembly (WRA) in the Digital Data Display Set (DDDS), part of the AV-8A/TAV-8A aircraft avionics. Reliability and Maintainability improvements are predicted for the DDI through the following modifications:

- a. Removal of reflector servo-drive assembly: use of fixed dual combiner with quick release assembly.
- b. Improved Cathode Ray Tube terminal ring circuit board: design of new board layout including additional protection diodes and surge voltage suppressor to reduce flash-over breakdown.
- c. In Test Mode 1, the display includes symbology in the format BF XXXX where the X's represent a decimal digit cumulative count of the number of times the built-in-test program in the SDC detects a transient malfunction of the SDC during the time the unit is energized.

Three DDI units have been successfully modified and tested. Recommendations have been made to retain the modified indicators at contractor's location for further system and flight test use.

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1. BACKGROUND

- 1.1 The Pilot's Display Unit (PDU), Figure 1, nomenclature 402 SUM/1, has been used as a part of the HUD system in the AV-8A and the TAV-8A aircraft for several years.

As a part of the improvement program on the PDU, the nomenclature was changed in September 1978 by the Naval Air Engineering Center, and the modified PDU was designated the Digital Display Indicator (DDI), IP-1351/AVQ-30(V), Figure 2. The manufacturer's part number is 10-108-01.

The DDI receives signals from either the Waveform Generator (202 SUE/5), or from the new Signal Data Converter, CV-3600/AVQ-30(V); and displays symbology for weapons-aiming, navigation, and aircraft flight status.

1.2 PURPOSE OF CONTRACT

- 1.2.1 The purpose of Contract Number N00019-77-A-0350-WW04 was to improve the reliability and maintainability of the PDU. Analysis indicates that a substantial increase in both reliability and maintainability will be achieved in operational use. See Paragraph 2.2.

1.3 EQUIPMENT DESCRIPTION

- 1.3.1 The DDI uses a cathode ray tube (CRT) and a lens system to project an information display of digital and analog symbols onto a semi-transparent glass reflector (combining glass) which is in the pilot's line of sight. The display is collimated, i.e., focused to infinity, so that it is superimposed on the external view ahead. The DDI provides sufficient information to allow the pilot to fly the aircraft through any maneuver or flight profile with a minimum of reference to the panel mounted instruments.

- 1.3.2 Information is presented in several distinct modes which provide the pilot with navigation, weapon-aiming, and air data in his normal head-up field of view, focused at infinity.
- 1.3.3 The DDI receives data from the SDC, and converts this data into symbols on the CRT. The brightness range of the CRT is pre-set by the ground crew using the Display Set Control (DSC), C-10626/AVQ-30(V). A manual brightness control is provided on the DSC for pilot use to set the desired display intensity. In addition, an automatic brightness control subsystem operates in the DDI to keep the pre-set brightness-to-background ratio constant as changes occur in the background illumination levels during flight. The auto brightness control subsystem uses a remote solar cell which supplies a voltage whose amplitude is proportional to the background brightness.
- 1.3.4 A modification to the DDI display in Test Mode 1 was made to aid in SDC failure analysis, maintenance, and as a confidence check. In Test Mode 1 the display includes symbology beneath the aircraft symbol in the format BF XXXX where BF represents Bit Fail and the X's represent a decimal digit count of the cumulative number of times the automatic built-in test program in the SDC detects a transient malfunction of the SDC during the time the unit is energized. In case of a hard failure of the SDC, the count will continue to 9999 and stop, counting at the rate of 40 counts per second. Figure 3 shows the symbology with 10 BIT failures, as
BF 10
- 1.3.5 The DDI, shown in Figures 1 and 2, consists of a Tube Assembly, a Lens Assembly, a Combiner Assembly, and a Chassis Assembly. The Tube Assembly is a separately air tight sealed, machined light alloy casting containing the CRT, the termination ring assembly, electromagnetic deflection coils, focus magnet, auto brightness circuits, and is fitted with a silica-gel desiccator. The Lens Assembly is a detachable, self-contained component consisting of a collimating four-inch f 0.97 folded lens system. The Chassis Assembly contains two connectors. Connector PL2 carries the 15,000 volts from the power supply (PP-7533/AVQ-30(V)) unit, and PL3 carries the symbol data and power from the SDC. The Chassis Assembly

also contains a braided wire to provide airframe ground to the DDI. The Combiner Assembly consists of a support frame and two gradiently coated combiner glasses. The Combiner Assembly is readily detached from the Chassis Assembly without the need for tools, to facilitate both removal and installation of the DDI, and windscreen cleaning.

2. R&M CONSIDERATIONS

2.1 The MFHBF* of the PDU has been steadily degrading and is currently approximately 300 hours. Frequent failures occur in the servo-controlled combiner assembly and in the electronic circuits on the termination ring of the CRT due to high voltage flash-over or arcing. This prediction is based on the following two modifications which are expected to eliminate the above failure modes:

- a. Replacement of the present servo-controlled combiner assembly with a fixed dual combiner assembly, which will provide an increased Instantaneous Field of View (IFOV) in elevation from 12° to 17° .
- b. Replacement of termination ring assembly with a new ring assembly consisting of an improved circuit board layout, improved protection diodes and with the addition of a surge voltage suppressor.

2.2 RELIABILITY PREDICTION

The reliability calculation for the PDU is based on recent actual flight and maintenance data which consists of 35,055 flight hours and 116 confirmed failures. The DDI prediction is based on a reduction in the number of failures which will result from the incorporation of the modifications.

2.2.1 Historical Data

During the analysis period the observed MFHBF for the PDU was 302 hours. During this period, 53 failures were attributed to the servo-controlled combiner assembly which is to be replaced with a fixed dual combiner assembly. The termination ring assembly experienced 11 failures. Therefore, 64 of the 116 failures are related to the proposed modifications.

*Mean Flight Hours Before Failure

2.2.2 Reliability Prediction

The 116 failures will be reduced to 52 by the failure modes eliminated as a result of the modifications.

This yields the following:

$$35,055 \text{ hours} \div 52 = 674 \text{ hours MFHBF}$$

This result assumes that the redesign configurations will have no additional failure modes. This is a reasonable assumption in the case of the combiner assembly which has no moving or electronic parts. The redesigned termination ring reliability prediction based on MIL-HDBK-217B, for 35,055 hours, shows that a maximum of two failures would occur in the termination ring assembly.

This yields a DDI reliability prediction of:

$$35,055 \text{ hours} \div (52 + 2) = 649 \text{ hours MFHBF at } 80^{\circ}\text{C}$$

The reliability goal stated in an earlier life cycle cost analysis was 500 hours. Therefore, this goal appears to be readily attainable.

The previous MTBF of the PDU was 302 hours. This has now been increased to 649 hours, based on the new improvements.

2.3 MAINTAINABILITY

As a result of the addition of the quick-release dual combiner which requires no tools, cleaning maintenance of the combiner glass, lens, and windscreen is greatly simplified. The removable combiner also facilitates removal and replacement of the DDI from the aircraft.

3. DESIGN MODIFICATIONS

- 3.1 The DDI is form-fit-function replacement for the PDU, 402 SUM/1. The only function not included in the DDI is the servo-driven combiner.
- 3.2 The design modifications to the PDU involve the replacement of the servo-driven combiner assembly with a removable fixed dual combiner assembly, which increases the pilot's IFOV from 12 to 17 degrees from the "design eye" position, and replacement of the termination ring assembly with a new assembly consisting of an improved component layout, protection diodes, and the addition of a surge voltage suppressor. The fixed dual combiner assembly is mounted on the main housing above the optical lens.

The total assembly weighs approximately 16 pounds. The savings in weight due to the design modifications is approximately one pound.

The servo motor and circuits draw 39 watts of power when in use. This power is saved in the new design.

- 3.3 The fixed dual combiner assembly which is a quick replaceable assembly (QRA), is a metal frame supporting two glass semi-reflectors approximately 1.25 inches apart and parallel with each other. Installation of the fixed dual combiner assembly on the DDI is facilitated by guide rails and alignment pins and the assembly is easily removed and installed with two quick disconnect fittings which provide repeatable loads on the combiner assembly fastening hardware. The two semi-reflectors are cemented in the support frame to ensure retention of their positions relative to each other.
- 3.4 The termination ring assembly is a part of the Tube Unit contained within the DDI. Access to the termination ring assembly requires disassembly of the DDI to permit removal of the Tube Unit. The Tube Unit is, in turn, disassembled to permit fault isolation or replacement of the termination ring assembly.

3.5 Only one non-standard part was used - a Surge Protector, which was approved for use by the Naval Avionics Center by NAC letter, 445:JFH:ca, 3963/RS7397, dated 8 August 1979.

3.6 The physical fit and function of the DDI is the same as the PDU. However, due to the configuration and orientation of the dual combiner, the clearance between the reflector and aircraft windscreen is approximately one centimeter. Since this severely limits access to the back of the reflector and to the lens for cleaning when the DDI is installed in the aircraft, the dual combiner assembly is designed to be a QRA. This QRA feature allows access for windscreen cleaning without removal of the entire DDI, thereby reducing "O" level maintenance time. The QRA feature is accomplished with two preset torque thumbscrews to assure repeatable torque application.

Using the QRA feature, at the O-level of maintenance, time savings of 9.5 minutes in cleaning the windscreen, 5 minutes in cleaning the combiner glass, and 15 minutes in removal of the DDI are estimated. The total O-level time savings for 72 aircraft is estimated at 3,072 hours per year.

4. TESTS AND ANALYSES

- 4.1 Tests and analyses performed on the DDI's are detailed in CDRL B008 "Test Procedures", Parts I - V. Part I, Performance and GSE Compatability Test Under Laboratory Conditions, was successfully performed without failure on each DDI, and the results are included in the Test Report. During the test, minor changes and clarifications to the Test Procedures were found necessary. These changes were incorporated into the Test Procedures as Revision D, dated 8 August 1979.
- 4.2 Test Procedures Part II, Burn-In was not performed as described in the procedure. An effective burn-in was achieved during the environmental tests, however. Permission for this procedure was granted by the Navy.
- 4.3 Test Procedures Part III, Performance Tests Under Simulated Environmental Conditions, included vibration, temperature, acceleration, and crash safety tests on DDI Serial #001.
- 4.3.1 There were no failures during the temperature test.
- 4.3.2 There were no failures during the acceleration test.
- 4.3.3 There were no failures during the crash safety test.
- 4.3.4 During the vibration test, DDI Serial #001 failed the operational and performance check, the display being rotated clockwise or counter-clockwise due to the vibration. This failure was a non-relevant failure, due to a mechanical failure of the deflection coil separating from its support sleeve. This failure was repaired and the test was completed satisfactorily.
- 4.4 Test Procedure Part IV, Interference Tests, involved a measurement of the influence of the DDI on the magnetic compass. This test was run on DDI Serial #001 in a magnetically shielded room at Martin Co. in Orlando, FL. The compass safe distance, the minimum spacing between the DDI and a magnetic compass causing a 1° deviation, was found to be well within the allowable limits.

- 4.5 The R&M tests described in Task C of the PDU section of the contract were deleted by the Navy in NAVAIR letter of June 4, 1979, Ref. 54911B/23/DCC; and in Contract Amendment E, dated 11 September 1979.
- 4.6 The Bump Test described in Task B of the PDU section of the contract was deleted by the Navy in NAVAIR letter of July 13, 1979, Ref. 54911B/026/DCC.
- 4.7 Flight tests were run at NATC, 22-30 August 1979, with the SDC, DDI and DSC installed.

Eight flights were made, totalling 7.7 hours with operation up to 35,000', up to mach 0.85, with 7.5 g turns, and hovering. The performance of the DDI was fully satisfactory during these flights.

5. SUMMARY OF IMPROVEMENTS

- 5.1 The weight of the display unit has been reduced by one pound.
- 5.2 The instantaneous vertical field of view has been increased from 12° to 17°.
- 5.3 The combiner assembly has been made readily removable without the need for tools to facilitate cleaning of the windscreen, combiner glass, and lens assembly. This feature also facilitates removal and replacement of the DDI from the aircraft. This reduces the O-level maintenance time and helps assure cleaner optics.
- 5.4 The reliability has been improved from a performance of 302 hours MFHBF to a calculated level of 649 hours MFHBF at 80°C.
- 5.5 The parts count has been reduced by the elimination of the servo motor, gearing, bearings and circuits. The reduction in the number of parts stocked at the I-level is 95, from 332 on the 402 SUM/1 PDU to 237 for the DDI.

6. CONCLUSIONS AND RECOMMENDATIONS

- 6.1 The DDI portion of the contract has been successfully fulfilled as projected, by performing the modifications required to improve system reliability and maintainability factors. All testing has been satisfactorily completed and documented.

The three DDI's, Serial Numbers 001, 002, and 003, which include the dual combiners, are in a ready-for-issue status. It is recommended that these units be kept at SI Inc. for use in future laboratory and flight tests of the SDC and the Digital Interface Weapon Aiming Computer.

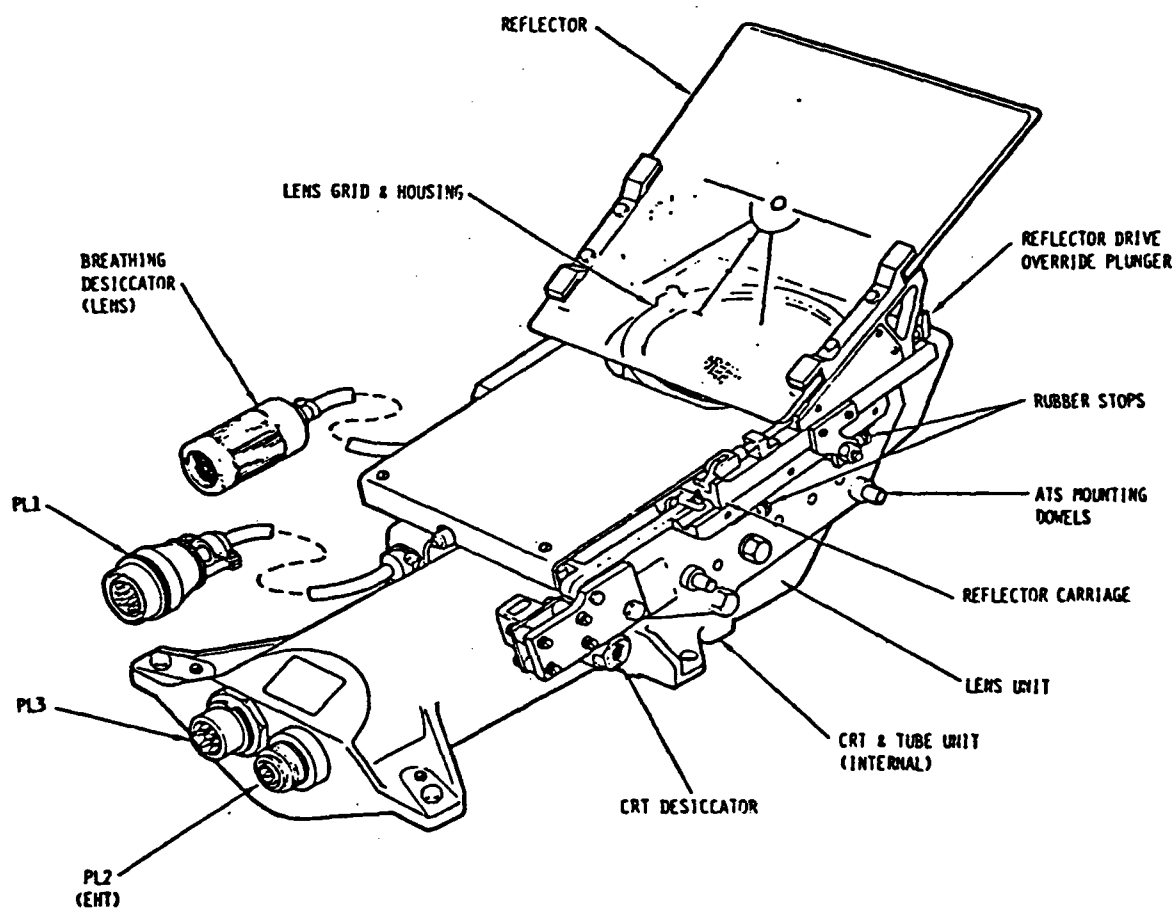


Figure 1. Pilots Display Unit Part No. 402 SUM/1
(Before Modification)

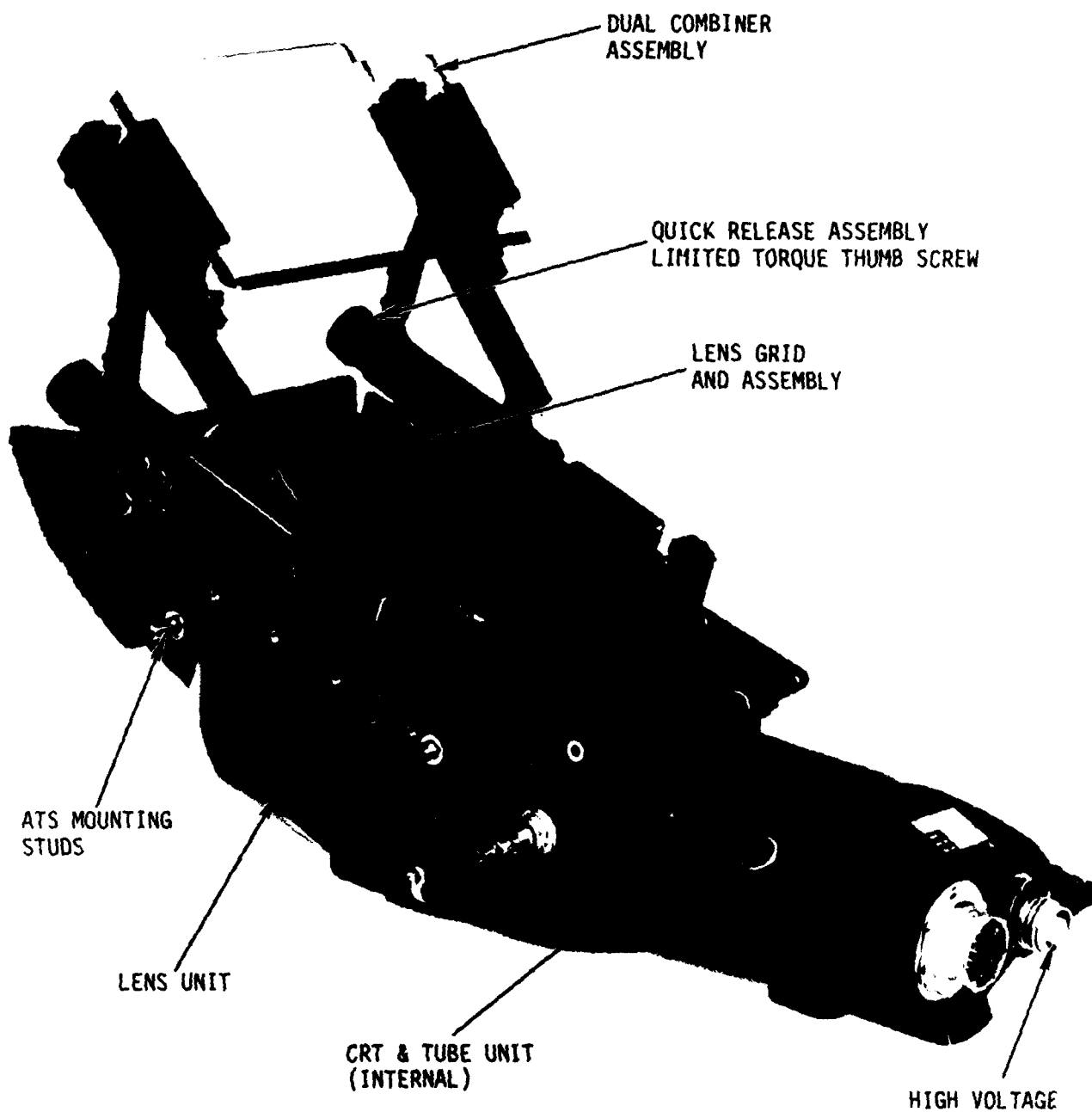


Figure 2. Digital Display Indicator, Part No. IP-1351/AVQ-30(V)

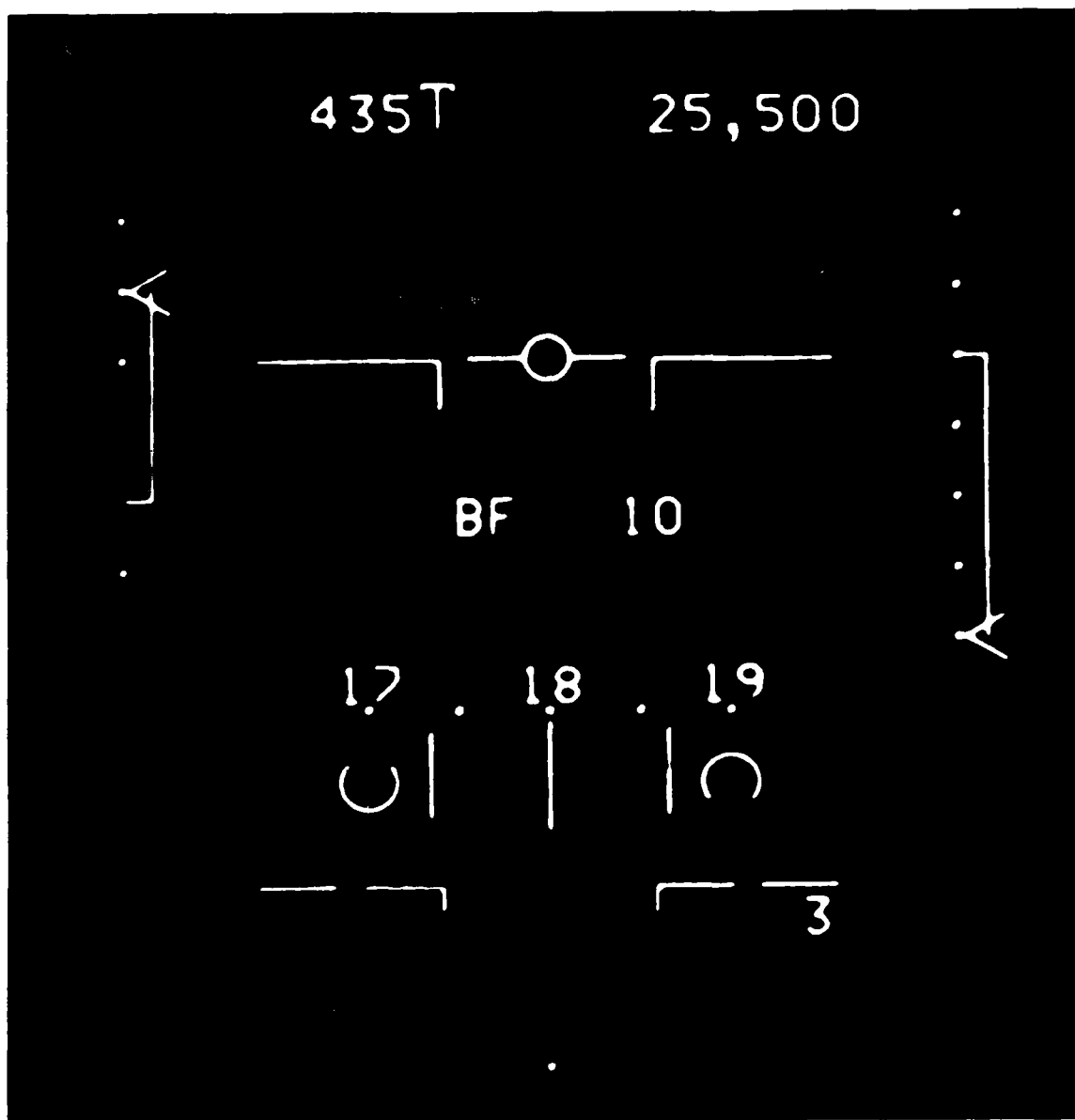


Figure 3. Test Mode 1 Symboly